CEOS Disaster Risk Management for Societal Benefit

Presented at the HyspIRI Data Product Symposium
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GROUP ON EARTH OBSERVATIONS

Committee on Earth Observation Satellites

Context/Overview

- Purpose – to improve delivery of satellite data and products for societal benefit in local/regional setting, but on a global scale
- Method - develop and infuse Earth Observation (EO) monitoring and modeling technology for data acquisition, processing, and product distribution for disaster applications
  - Sensor Webs and applied science research
- Experience - based on Committee on Earth Observation Satellites (CEOS) and Group on Earth Observations (GEO) activities
  - CEOS Disaster Risk Management (DRM) Pilots address ground validation, crowd sourcing, and hand-held clients to validate disaster products and services
  - Capacity building to infuse standardized web servers and clients that provide open access to critical disaster management information, data, and maps via the internet using common, open desktop tools
- Link to presentation for GeoSocial API
  - https://www.dropbox.com/s/t15lvyriw3c20nl/AIP7%20Plenary%20Presentation%20May%2027%202014.pptx
- Link to presentation for OJO GeoApp
  - https://cappelaere.wistia.com/medias/faz1hi8bpu

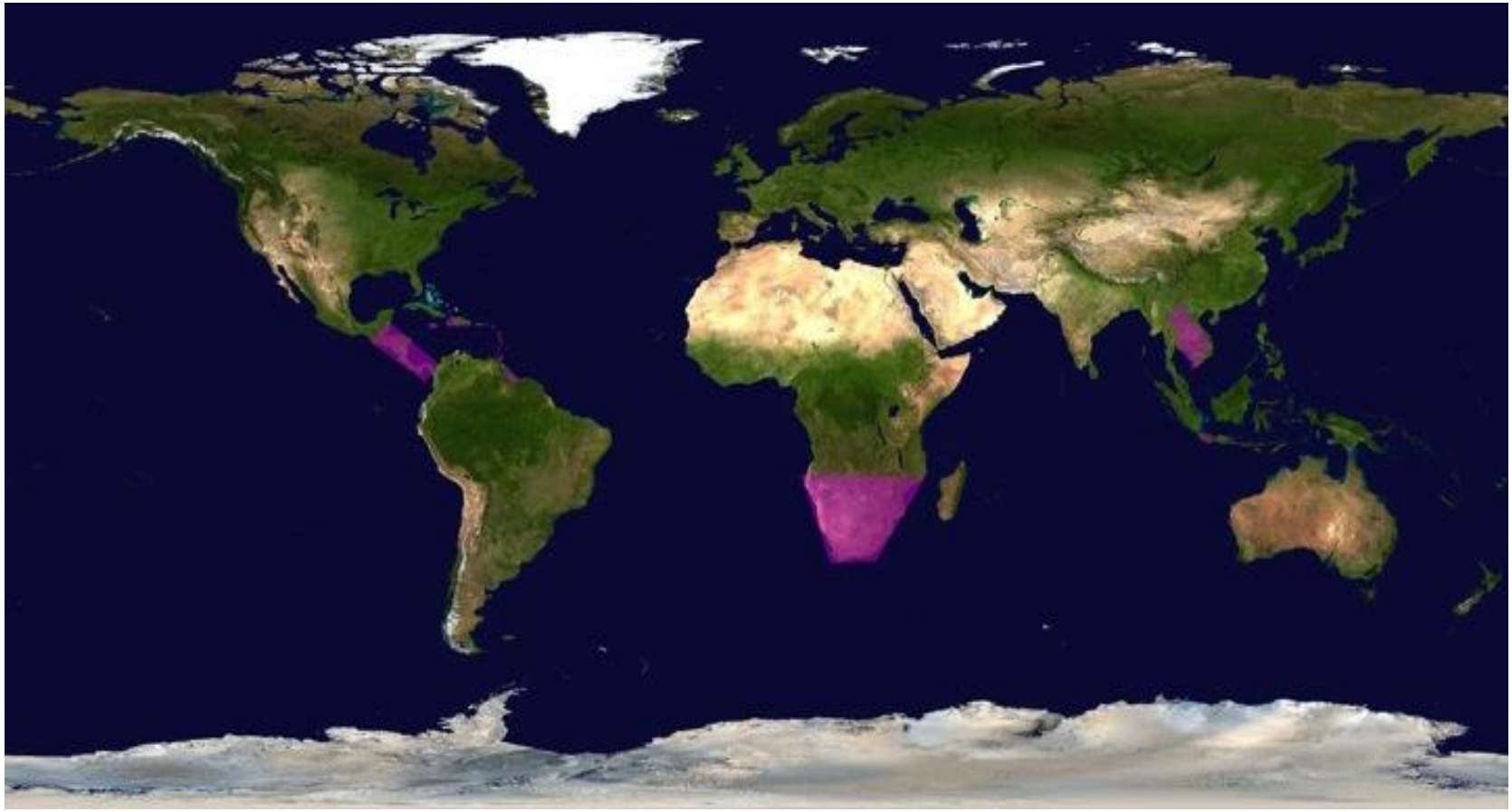
CEOS DRM Pilots Overview

Pilot	Team Co-Leads	Deliverables
Floods	**NASA**, S. Frye **NOAA,** B. Kuligowski	• **Global Flood Dashboard (single access for multiple existing systems)** • **Three regional pilots showcasing end user benefit of frequent high spatial resolution observations (Caribbean, Southern Africa, Mekong/Java)**
Seismic Risks	**ESA,** P. Bally **DLR,** J. Hoffmann	• **Demonstrator for EO-based global strain map** (main focus on Turkey, Himalayas and Andes) • **Exploitation platform for large data set analysis (strain map, supersites)** • **Rapid scientific products for 4 to 6 earthquakes per year (>M5.8)**
Volcanoes	**USGS,** M. Poland **ASI,** S. Zoffoli	• **Demonstrate feasibility of systematic global monitoring in regional arc (Latin America)** • **Develop new EO-based monitoring products at supersites** • **Real-time in-depth monitoring of one '100-year' category major eruption**

Target areas for Flood Pilot EO data

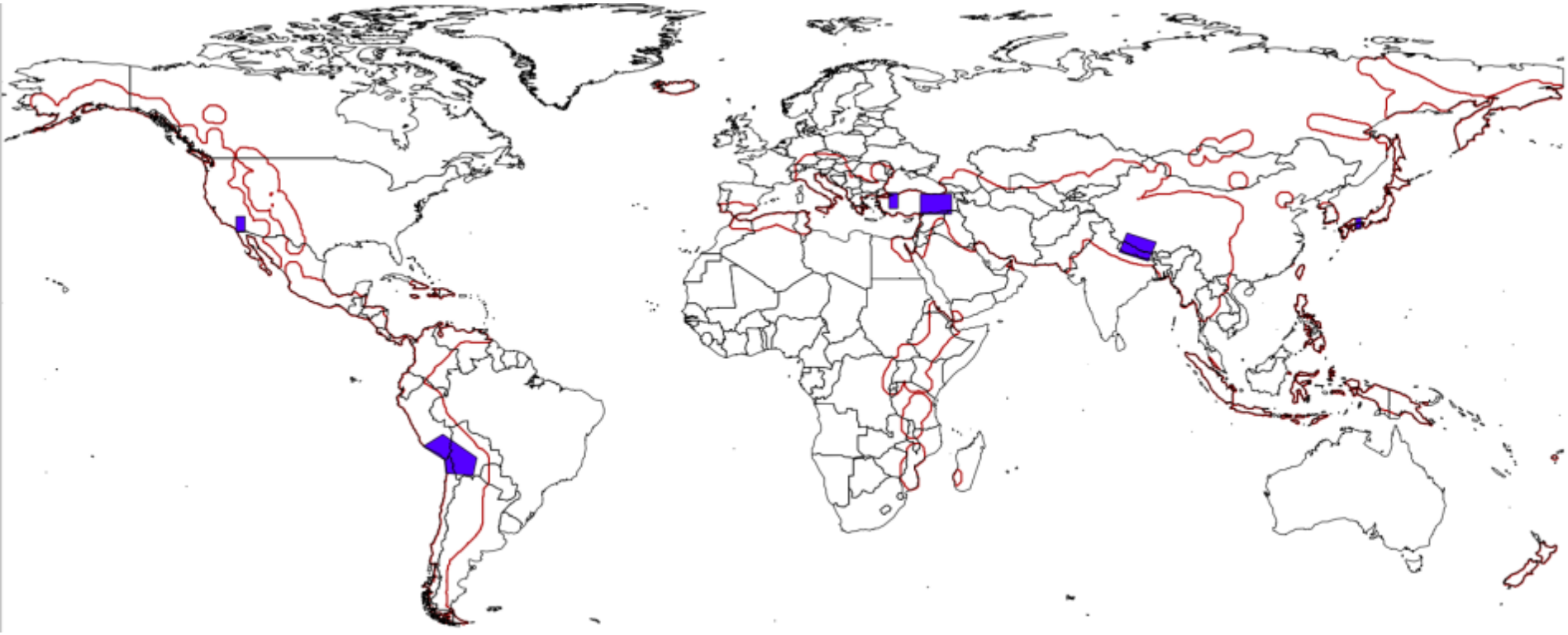
D**evelop flood monitoring products for flood mitigation, warning, response and recovery in the Caribbean/Central America, Southern Africa and Southeast Asia**. Use these regional pilots to validate/calibrate lower resolution global flood products and to develop capacity in region.

Mesoamerican countries eligible for no-cost Radarsat-2 acquisitions include Haiti, Virgin Islands, Barbados, Grenada, Jamaica, St Lucia, Dominican Republic, Anguilla, Belize, Guatemala, Guyana. Honduras, Nicaragua, Costa Rica, Dominica, and Panama, Caicos, St. Kitts, Antigua, Trinidad, Tobago, Cayman Island, Nevis, Montserrat, Guadeloupe, Martinique, Aruba, Curacao, St. Martin, St. Vincent, Grenadines, Yucatan Peninsula, Belize, Guatemala, Honduras, Costa Rica, Colombia, and Venezuela

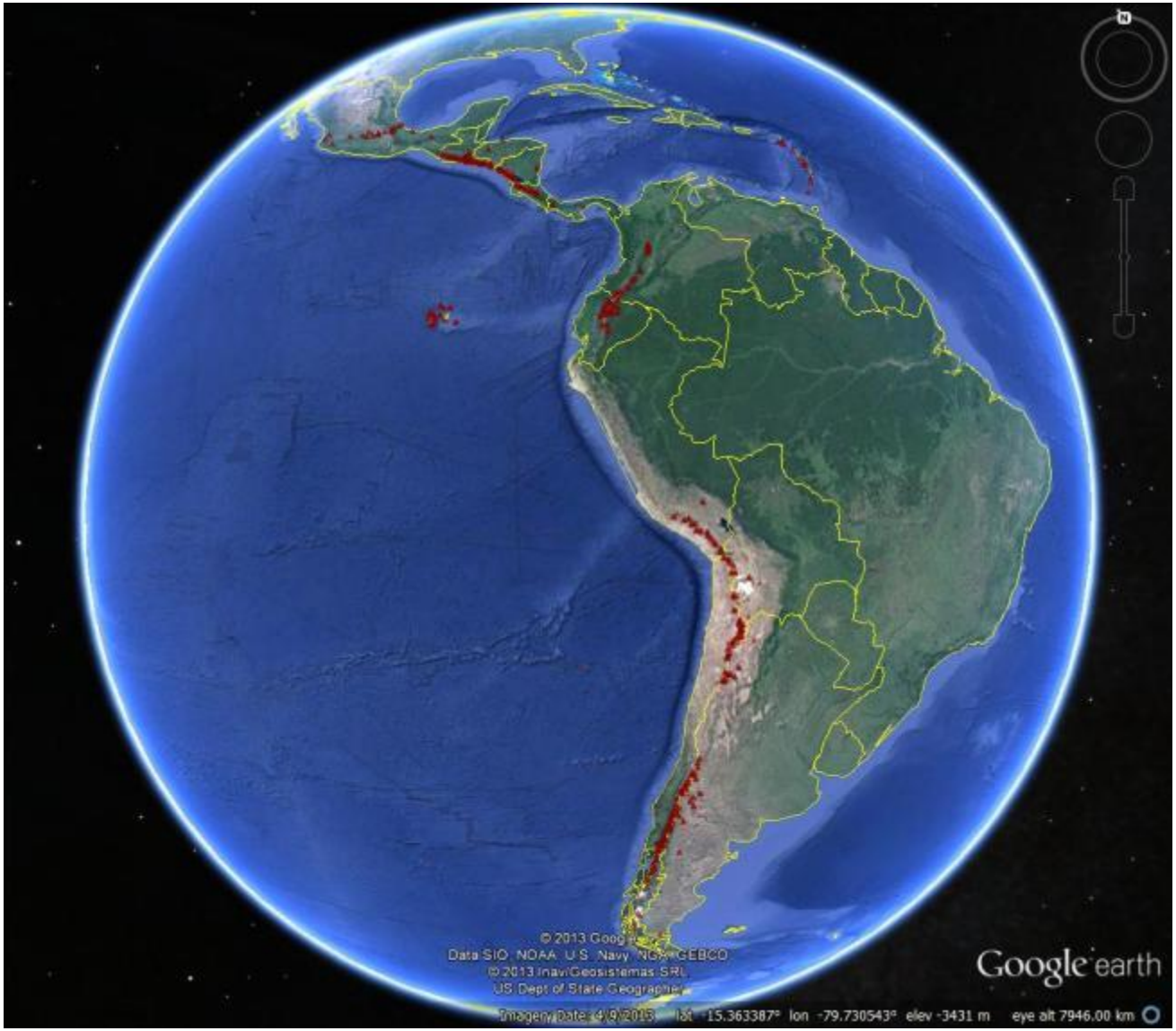


Target areas for Seismic Pilot EO data

Portions (in purple) of the global seismic belt including the Alpine-Himalayan Belt (incl. Turkey, Iran, Tibet, etc.), subduction zones in South America, with validation sites in Southern California, Western Turkey and Southern Japan. Gradually extend to red zones beyond current pilot.



Target Areas for Volcano Pilot EO data



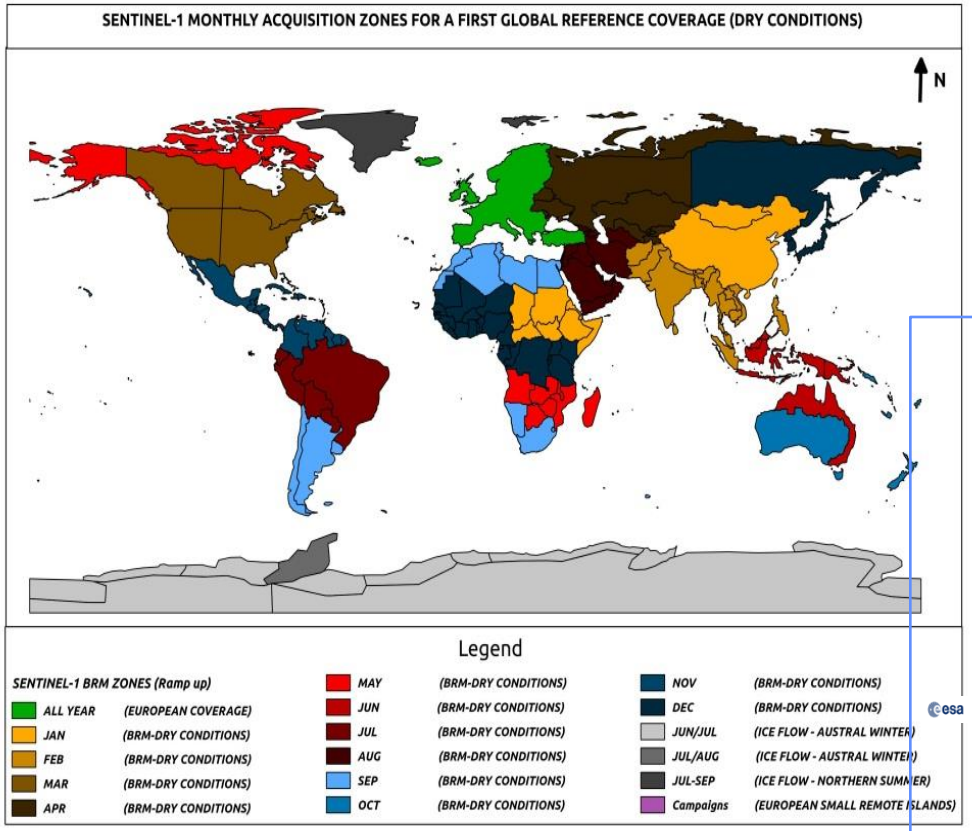
CEOS Agency Response to Pilots: Strategic EO Data Acquisition Plan

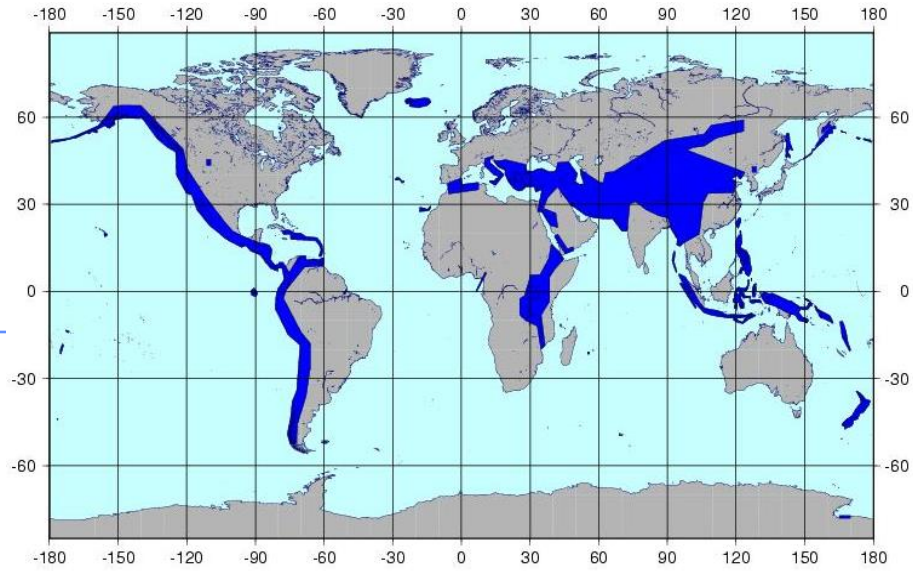
- **Detailed EO Requirements for each pilot approved at last Plenary**
  - **Pilot definition included types of data required, frequency of observations and polygons of interest, etc**

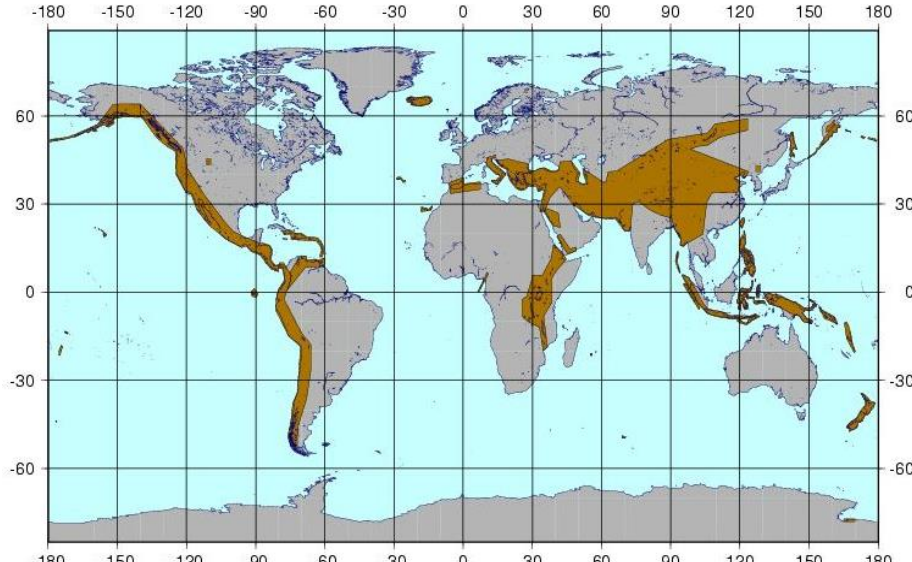
- **Pilot EO Requirements submitted to Data Coordination Team made up of representatives from CEOS agencies**

- **Assessment of EO Requirements between last Plenary and SIT-29 by each individual agency**
  - **Agencies' responses analysed and consolidated by Data Coordination Team and pilot Leads. *(WGDisasters meeting # 1, Montreal 17-19 March)***
  - **Analysis included trade-offs between pilots *(e.g. Pleiades data to be used in priority for volcanoes and seismic hazards),* synergies across pilots *(volcanoes and seismic hazards)* and possible overlaps with other major initiatives *(GEOGLAM, GFOI in S-E Asia, Supersites)***

Analysis from Space Agencies







Data Contributions* from CEOS Agencies (1/3)

CEOS Agency	Flood Pilot	Seismic Pilot	Volcano Pilot
ASI Proposed contribution under review.	Approximately 300 CSK images/year/pilot over three years, in addition to existing GSNL commitments. Priority given to archived imagery. NRT images for rapid science products under Flood Objective B, Seismic Objective C (1-2 events/year) and Volcanic Objective C (1 major eruption) to be evaluated on case by case basis.		
CNES NRT imagery request being discussed with commercial partner	SPOT World Heritage Archive made available to pilots (1000s of SPOT-5 archived images) with five-year rolling buffer. Up to 50 Pleiades images/year/pilot over three years. Commitment to be finalized after discussions with industrial partner. Night-time SPOT-5 imagery during 2014. ANR KalHaiti data base over Haiti.		
CSA Review against commercial conflict required.	About 500 RSAT-2 products to support the Flood Pilot until November 2016 (end of the Pilot). More than 400 RSAT-2 products to support GSNL i.e. Hawaii (ongoing) and Iceland (in negotiation with MDA). Potential access to Volcano Watch Background Mission over Latin America (archived RADARSAT-2 products). Data for rapid science products for Seismic and Volcano Pilots evaluated on case-by-case basis: contribution of 40 RSAT-2 products for Event Supersite: Sinabung Volcano, Indonesia.		

***contributions are in addition to existing GSNL contributions and International Charter data made available during or after activation**

Data Contributions* from CEOS Agencies (2/3)

CEOS Agency	Flood Pilot	Seismic Pilot	Volcano Pilot
ESA Sentinel-1 launch April 2014. Six months commissioning. Sentinel-2, SMOS.	Sentinel-1 gradually made available starting with pilot targets in 2014 when these converge with baseline observing strategy. +20000 scenes over Italy, Japan, California, Turkey & Greece the first year overall for 3 pilots	Sentinel-1 gradually made available starting with pilot targets in 2014 and with the goal to cover priority areas of Objective A for 2016 – 10s of 1000s of images	Sentinel-1 gradually made available starting with pilot targets in 2014 and with the goal to cover priority areas of Objective A for 2016, especially when these converge with seismic areas
DLR Proposed contribution under review. Review against commercial conflict required.	200 TSX scenes over three years; access to TanDEM Elevation Model without data transfer (through viewer) being considered	Assessment of validation areas and data volumes (Objective A) under way. Possible access to TanDEM Elevation Model without data transfer being considered.	400 TSX scenes over three years (under Obj. A); contribution to Obj. C to be evaluated after eruption; access to TanDEM Elevation Model for erupting volcano being considered.
JAXA Proposed contribution under review. ALOS-2 launch May 2014.	100 ALOS-2 products/year/pilot made available for promotion/demonstration; additional data available at marginal cost of $100/scene; barter arrangements for further data requests under review. Acquisitions requested are covered by ALOS-2 Basic Observation Scenario		

***contributions are in addition to existing GSNL contributions and International Charter data made available during or after activation**

Data Contributions from CEOS Agencies (3/3)

CEOS Agency	Flood Pilot	Seismic Pilot	Volcano Pilot
NASA EO-1 estimated end of life 2016	300 EO-1 images/year 2014-2015	JPL/ARIA to provide rapid processing for 2-4 events/year under Objective C	Hyperion data for lava temperature and structure information (approx. 100 images/year 2014-2015)
NOAA	Precipitation products; flash flood warning system in regional pilot areas	N/A	Atmospheric data products over Latin America
USGS Further tasking of Landsat-8 possible if required	Landsat-8 imagery	Landsat-8 imagery	Night-time tasking of Landsat-8 over 19 active volcanoes in Latin America

***contributions are in addition to existing GSNL contributions and International Charter data made available during or after activation**

How data will be exploited – flood pilot

Geographic Area	Product	Value Added Partner
Haiti	Flood extent maps, flood risk maps, landslide maps, flash flood guidance / threat maps, integrated risk assessment platform	SERTIT, CIMA, INGV, Altamira, CIMH, RASOR FP7, NOAA/HRC
Other Caribbean islands, Central America	Flood damage maps, change detection products, co-registered map overlays	CATHALAC, CIMH, NASA/GSFC
Namibia	Flood extent maps, flood warning products, co-registered map overlays	Namibia Hydrology Dept, Namibian Water Authority, NASA
Zambezi basin	Flood extent maps, flood forecast models, flood hazard maps, flood depth forecasts	Lippmann Institute (PAPARAZZI, HAZARD, WATCHFUL), DELTARES, NASA/JPL
Mekong	Flood extent maps, flood risk maps, flash flood guidance / threat maps	Mekong River Commission, NASA, NOAA/HRC, USGS, University of South Carolina, Texas A&M
Java (Bandung, Jakarta, Cilacap)	Flood risk maps, subsidence maps tied to flood risk, tsunami risk maps (Cilacap only), flood extent maps	SERTIT, Deltares, CIMA, Altamira, INGV, RASOR FP7

Products used by: national end users, civil protection agencies, World Bank, Red Cross, River Commissions (Kavango, Zambezi, Mekong)

How data will be exploited – seismic pilot

Activity	Product	Value Added Partner
Wide extent monitoring for strain map generation	Interfermetric processing (conventional InSAR and PSinSAR) to derive strain rate estimates based on deformation measurements; Generation of fault mapping products; EO based urban footprint to support exposure mapping as supporting information for seismic risk analysis.	COMET+, ISTerre
Geohazard Supersites and Natural Laboratories	Interfermetric processing (conventional InSAR and PSinSAR) to derive interseismic, co-seismic and post-seismic deformation mapping products; Generation of surface fracture mapping products to support modelling of seismic sources and possibly map some large aftershock in the surroundings.	Various over each supersite and event supersite, on best efforts basis
Rapid generation of science products	Interfermetric processing (conventional InSAR and PSinSAR) to derive co-seismic and post-seismic deformation mapping products; Generation of surface fracture mapping products to support modelling of seismic sources and possibly map some large aftershock in the surroundings.	INGV, JPL/ARIA

Products used by: academia and researchers, civil protection agencies…

How data will be exploited – volcano pilot

Activity	Product	Value Added Partner
Regional volcanic monitoring in Latin America	Terrain deformation products over 300 volcanoes to identify unsuspected activity; weekly monitoring of 19 active volcanoes; thermal anomaly detection; atmospheric products during eruptions; ash dispersal and ash cover maps.	Bristol University, Cornell University, Open University, NOAA, Buenos Aires and Washington VAACS
Development of new methodologies and products for intensive monitoring over supersites	Using GSNL data collects over the volcano supersites, the CEOS pilot will develop and validate new monitoring protocols for active volcanoes and generate products that could be used for global monitoring of holocene volcanoes after the pilot period.	USGS, INGV, University of Iceland
Major volcano eruption 2014-2016	Pre-event deformation products if data available over volcano selected, to examine retroactively the benefit of deformation mapping in precursor phase Co- and Post-event deformation Co- and Post-event products for ground (ash cover, thermal monitoring etc.) Co- and Post-event atmospheric products (ash dispersal, SO2 monitoring etc.)	USGS/VDAP, Bristol, Cornell and others depending on eruption location

Products used by: national end users, civil protection agencies, volcanic observatories in Latin America, VAACS

Response to Pilots: CONCLUSIONS

- **Majority of contributions *(open & free data)* confirmed by Agencies. Some options still being worked (e.g. alternatives addressing some data policies constraints.**
  - **Main issue: data contributions are for R&D activity; should some activities become operational after 2016, funding is required to ensure sustainability**

- **Consolidated response from space agencies very positive; volume of EO data & products confirmed is similar or greater to what was initially provided for Forest Carbon Tracking and for JECAM.**

- **Main objectives of each pilot can be reached with the firm contributions announced.**

- **On-going refinement for data; some specific imaging requirements being reconsidered given trade-offs between agencies: how to best exploit synergies?**

User Challenges

- Users are split into three categories:
  a) Satellite operators and their value added providers,
  b) National agencies/ regional centers/ international organizations, and
  c) The general public (think weather app on your smart phone)
- Users b) and c):
  - Want products specific to their disaster event, not data they have to manipulate
  - Don’t want to program, they want to execute requests with point and click apps
  - Don’t want to purchase software tools, they want open source tools that are freely available and ubiquitous

User Challenges #2

- All users want products to be accessible using tools they usually have installed on their desktop or hand held devices
- Digital products are preferred over paper (important to disaster users we have in our regional pilots)
- PNG, PDF, and JPEG are nice for pictures in reports and presentations, BUT…
- Users want map based products such as
  - KML raster overlays and vectorized polygons
  - These can be combined with other data on a common map background for mashups/analysis/reporting

User Challenges #3

There are hidden services that the users will expect without necessarily knowing they need to ask for it.

•Situational awareness requires a stream of new data in addition to static overlays and archive data

- New acquisitions need to be visible to all users so they can know what to request for tomorrow and the next day, available from the variety of feasibilities that are provided

•Automated mapping servers and map service organizations need to have new data availability published and the capability to subscribe for notification of URL/URI of those data sets

•Product processing should be automated for every available user option – either for every data set or on-demand for specific detection and classification algorithms

User Challenges #4

More hidden services that the users will expect without necessarily knowing they need to ask for it.

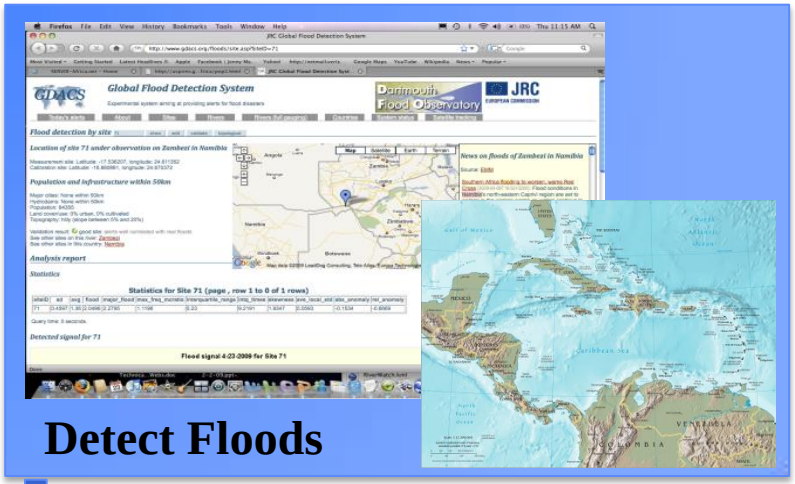
•Tiling and compression should be available for raster and vector-based products that can be ingested and visualized by desktop and hand-held devices without any programming knowledge

•Product publication and distribution can be via RSS or Atom-type feeds, but should evolve to become “product feeds”

•Product providers need to ensure that

- Native resolution is maintained
- Products are terrain corrected and co-registered to map control points
- Products are delivered only within the user area of interest (i.e., down scaling global-regional-local)
- Delivered products can be easily validated/corrected by non-experts

NASA Disaster Sensor Web Concept

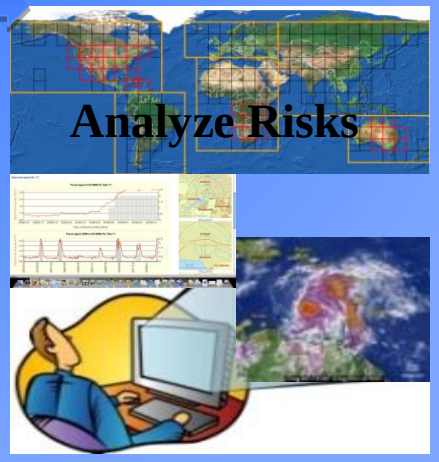


Detect Floods

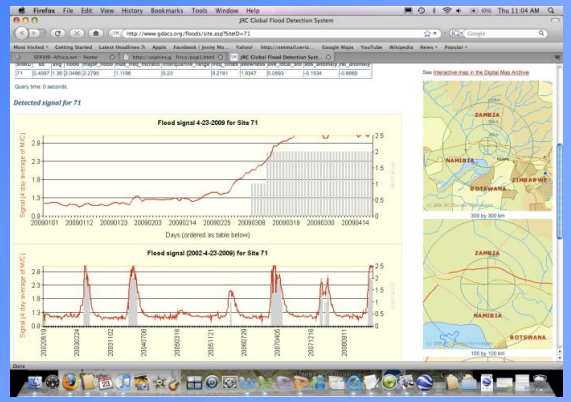
Initiate Request

Task Sensor

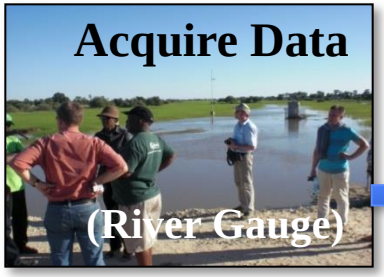
Acquire Data (Image)



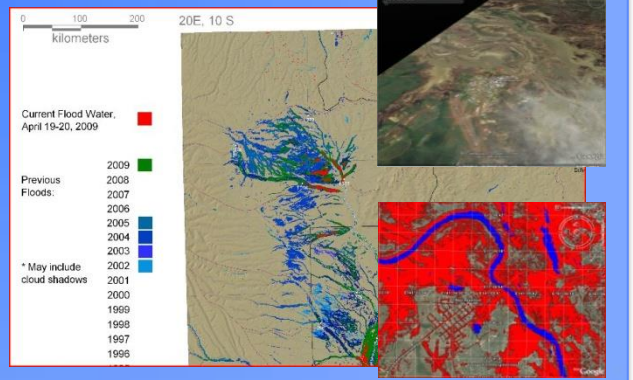
Analyze Risks



Validate Model



Acquire Data (River Gauge)



Analyze Image

Satellites for Flood and Drought Monitoring

Global Moderate Resolution

- Terra
- Aqua
- S-NPP
- TRMM
- GPM
- SMOS
- GCOM-W1
- SMAP
- GOES
- DMSP
- NOAA-19
- METOP
- METEOSAT

Pointable High Resolution

- EO-1
- Terra ASTER
- Radarsat-2
- Cosmo-Skymed
- TerraSAR-X
- Pleaides-1
- ALOS-2
- Sentinel-1
- Spot-5
- Worldview-2
- Landsat-8

Details for High Resolution Satellites

Category	Mission	Instrument	Agency	Launch	Repeat or Revisit *	Swath	Resolution
Optical - Coarse Resolution (>100m)							
Core	Terra	MODIS	NASA	Dec 1999	1 day	2330 km	250, 500, 1000m
Core	Aqua	MODIS	NASA	May 2002	1 day	2330 km	250, 500, 1000m
Core	NPP	VIIRS	NASA	Oct 2011	1 day	3000 km	375, 750m
Optical - Moderate Resolution (10 to 100m)							
Core	Landsat-8	OLI + TIRS	NASA/USGS	Feb 2013	16 days	183 km	15, 30, 100m
Core	Sentinel-2A	MSI	ESA	Feb 2015	10 days	290 km	10, 20m
Core	Sentinel-2B	MSI	ESA	May 2016	10 days	290 km	10, 20m
	EO-1	ALI	NASA	Nov 2000	2-4 days	185 km	10, 30m
C-Band SAR							
Core	Sentinel-1A	SAR	ESA	Mar 2014	12 days	80, 250, 400 km	9, 20, 50 m
Core	Sentinel-1B	SAR	ESA	May 2016	12 days	80, 250, 400 km	9, 20, 50 m
Core	Radarsat-2	SAR-C	CSA	Dec 2007	1-6 days	8-500 km	0.8 - 100m
Core	ALOS-2	PALSAR-2	JAXA	Dec 2013	14 days	25 to 490 km	10 to 100 m
X-Band SAR							
Contributing	TerraSAR-X	SAR	DLR	Jun 2007	11 days	5 to 100 km	1, 3, 16 m
Contributing	COSMO SkyMed	SAR-2000	ASI	Jun 2007	5 days *	10 to 200 km	1 to 100 m

Details for Global Coverage Satellites

Category	Mission	Instrument	Agency	Launch	Repeat or Revisit *	Swath	Resolution
Optical - Coarse Resolution (>100m)							
Core	Terra	MODIS	NASA	Dec 1999	1 day	2330 km	250, 500, 1000m
Core	Aqua	MODIS	NASA	May 2002	1 day	2330 km	250, 500, 1000m
Core	NPP	VIIRS	NASA	Oct 2011	1 day	3000 km	375, 750m
Core	JPSS-1	VIIRS	NOAA	Jan 2017	16	3000 km	375, 750m
Optical - Moderate Resolution (10 to 100m)							
Core	Sentinel-2A	MSI	ESA	Feb 2015	10 days	290 km	10, 20m
Core	Sentinel-2B	MSI	ESA	May 2016	10 days	290 km	10, 20m
SAR							
Core	Radarsat	Radar	CSA		5 days	500km	250m
Core	Envisat	ASAR	ESA		3 days	500km	250m
Core	ALOS	PALSAR	JAXA		7 days	500km	250m
Soil Moisture and Precipitation							
Core	SMOS	MIRAS (L-Band MW)	ESA	Nov 2009	1-3 days *	1050 km	40 km
Core	GCOM-W1	AMSR-2 (MW)	JAXA	May 2012	1-2 days *	1450 km	5 to 50 km
Core	SMAP	SMAP (L-Band MW)	NASA	Oct 2014	1-3 days *	1000 km	10 to 40 km
Core	GCOM-W2	AMSR-2 (MW)	JAXA	2016	1-2 days *	1450 km	5 to 50 km
Rainfall Rate							
Core	TRMM	TMI	NASA	Nov 1997	~12 hours	760 km	4.4 km
Core	GPM	GMI	NASA	Feb 2014	~3 hours	885 km	4.4 km
Core	DMSP F17	SSMIS	DoD	Nov 2006	12 hours	1707 km	14 km
Core	DMSP F18	SSMIS	DoD	Oct 2009	12 hours	1707 km	14 km
Core	DMSP F19	SSMIS	DoD	2014	12 hours	1707 km	14 km
Core	NOAA-19	MHS	NOAA	Feb 2009	12 hours	2348 km	17 km (nadir)
Core	METOP-B	MHS	EUMETSAT	Sep 2012	12 hours	2348 km	17 km (nadir)
Core	NPP	ATMS	NASA-NOAA	Oct 2011	12 hours	2300 km	15.8 km (nadir)
Core	GOES-West (current series)	Imager	NOAA	1995	15-180 min	Sectors and FD*	4 km (nadir)
Core	GOES-West (GOES-R series)	ABI	NOAA	Sep 2016	5-15 min	FD	2 km (nadir)
Core	GOES-East (current series)	Imager	NOAA	1994	15-180 min	Sectors and FD	4 km (nadir)
Core	METEOSAT (Second Generation)	SEVIRI	EUMETSAT	2002	15 min	FD	3 km (nadir)
Core	METEOSAT (Indian Ocean)	MVIRI	EUMETSAT	2006	30 min	FD	5 km (nadir)
Core	MTSAT-2	Imager	JAXA	2005	15-60 min	Hemispheric / FD	4 km (nadir)
Core	Himawari-8 (replaces MTSAT-2)	AHI	JAXA	2015	10 min	FD	2 km (nadir)

NASA Web Service URLs

- OpenID Provider-Server https://op.geobliki.com/ controls the security (this is where you setup your account)
- Campaign Manager http://geobpms.geobliki.com/home allows tasking requests to be submitted (i.e., target requests)
- EO-1 Server http://eo1.geobliki.com/ this is where EO-1 data can be found along with the status of future and past task requests
- Radarsat Server http://radarsat.geobliki.com/radarsat where we provide access to Radarsat-2 browse images, metadata, and processed flood products in several formats
- MODIS Flood Server http://oas.gsfc.nasa.gov/floodmap/ is where you can point your browser to manually check on daily MODIS flood maps (browser GUI-based only)
- MODIS Flood Server API http://modis.geobliki.com/modis is the server that provides an Application Programmer Interface (API) for accessing the daily MODIS maps

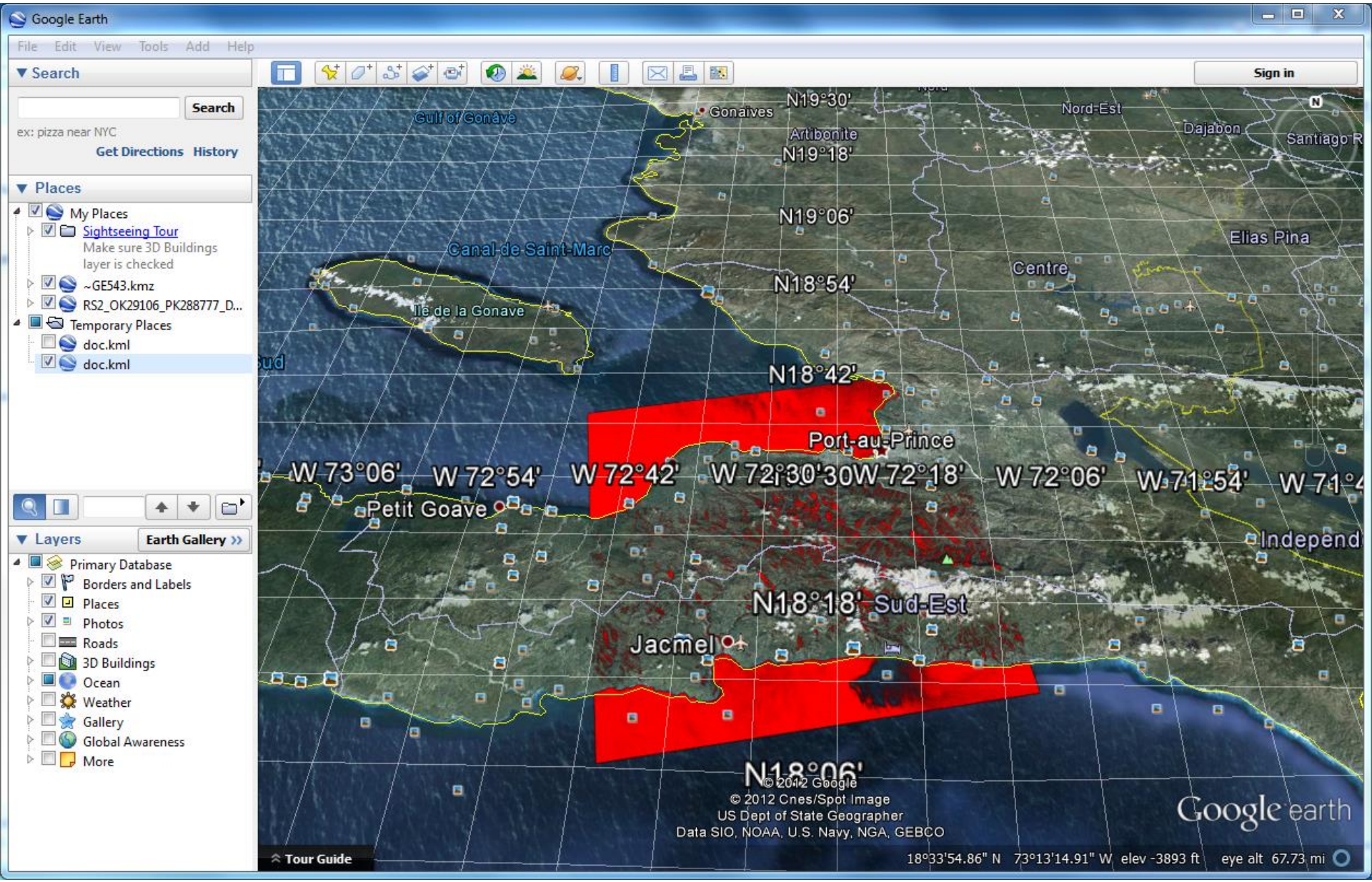
NASA URLs Concluded

- Flood Dashboard Client http://matsu.opencloudconsortium.org/namibiaflood this is an example of a client implementation that runs on a cloud computing platform provided through a collaboration with the University of Illinois/Chicago and Open Cloud Consortium
- Web Coverage Processing Service (WCPS) http://matsu.opencloudconsortium.org/wcps/session/login is for generating and executing algorithms against satellite data
- Pub/Sub Server http://opsb.geobliki.com/session/new is for setting up subscriptions to be notified when new products of interest to you are published….The notifications come via Email, SMS, or twitter and contain RSS or Atom feeds for you to follow to find the product. Clients can be automated to monitor the feeds and pull the data they are programmed to look for

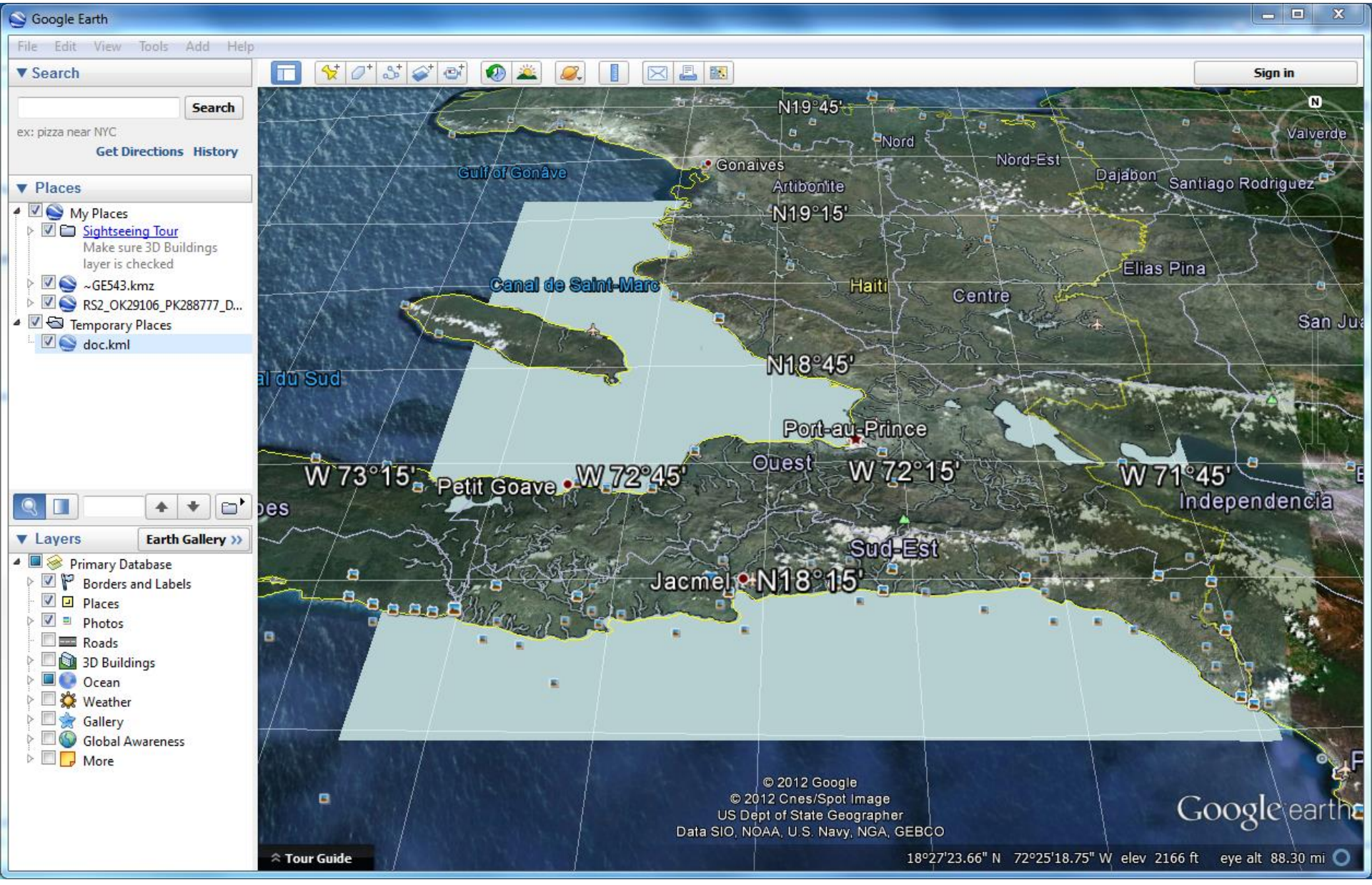
NASA URLs, server descriptions, and instructions available at

http://eo1.gsfc.nasa.gov/new/sensorWebExp/SensorWebReadMore.html

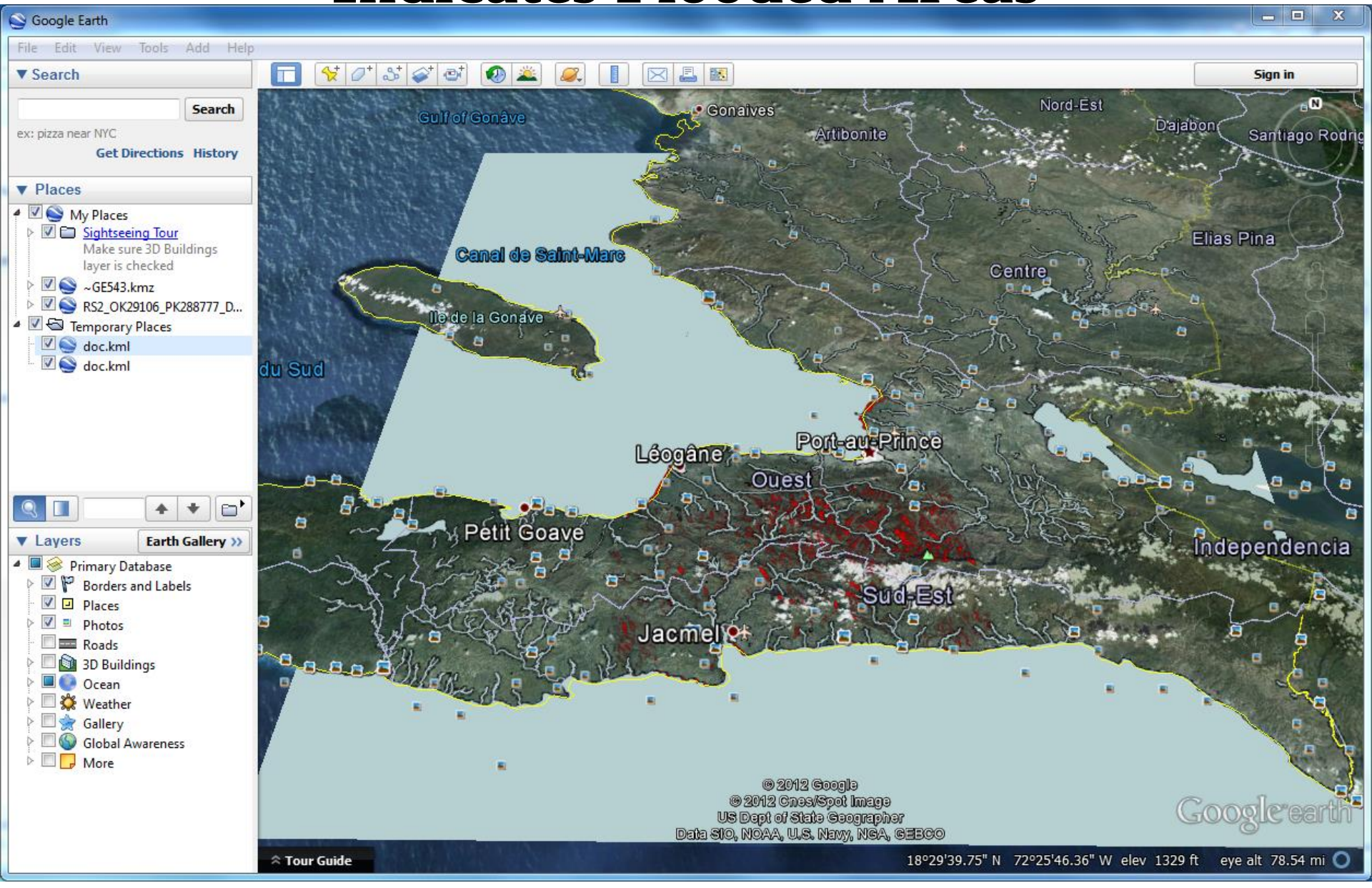
Radarsat-2 Water Detection Example (red)



Open Street Map Reference Water (blue)



Combined Overlays (blue on red) Indicates Flooded Areas



Landsat 8 example in Haiti for construction of reference water mask

LC80090472013117LGN01 vis_composite (5-4-3) (EPSG 4326) TIF Compressed 76.4MB

Using WCPS

Original Data Set 8 OLI Bands TIF 108.7MB each (7461x7281 pixels 30m resolution)

Surface Water Detection Product

Using WCPS

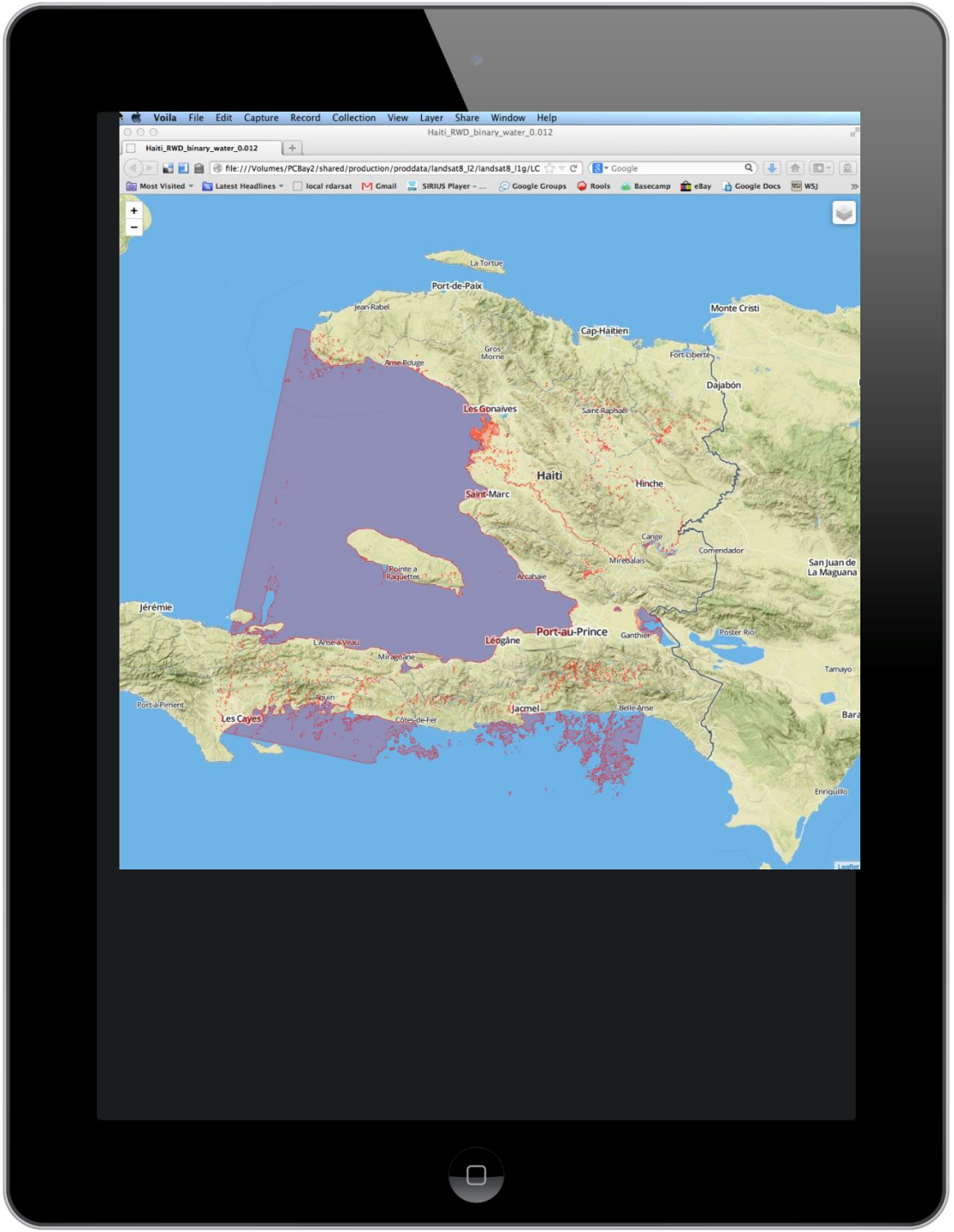
5.9MB TIF LZW Compressed

Note: Particular Algorithm is Not Relevant In this Example

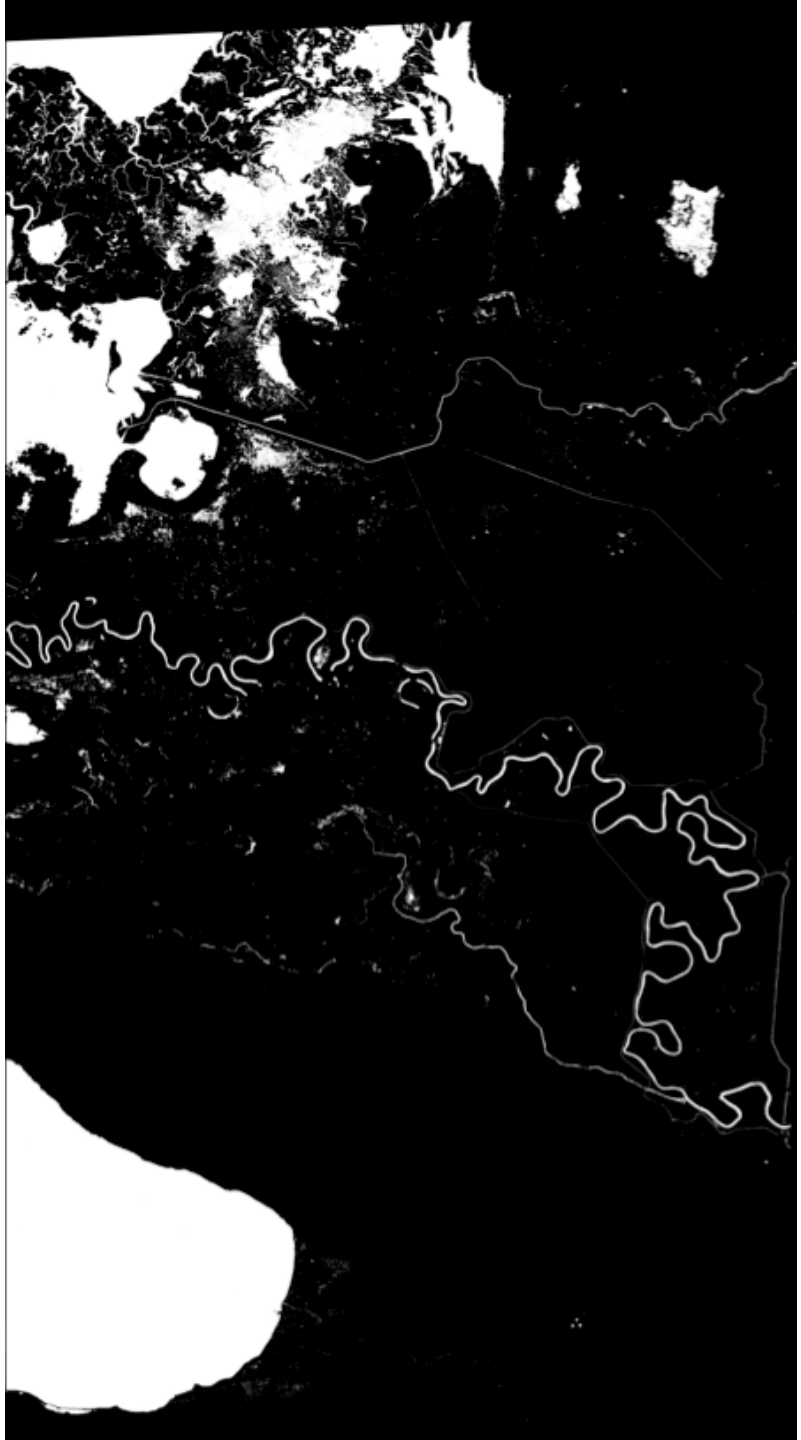
Resulting Product On Mobile Browser

Mapbox.js, MapBox Terrain Layer…

Other Layers Can be Added From OpenStreetMap such as Reference Water…
Or Population Density…



Final Achievement:
Product Compressed Size From:
2.2MB to 350KB



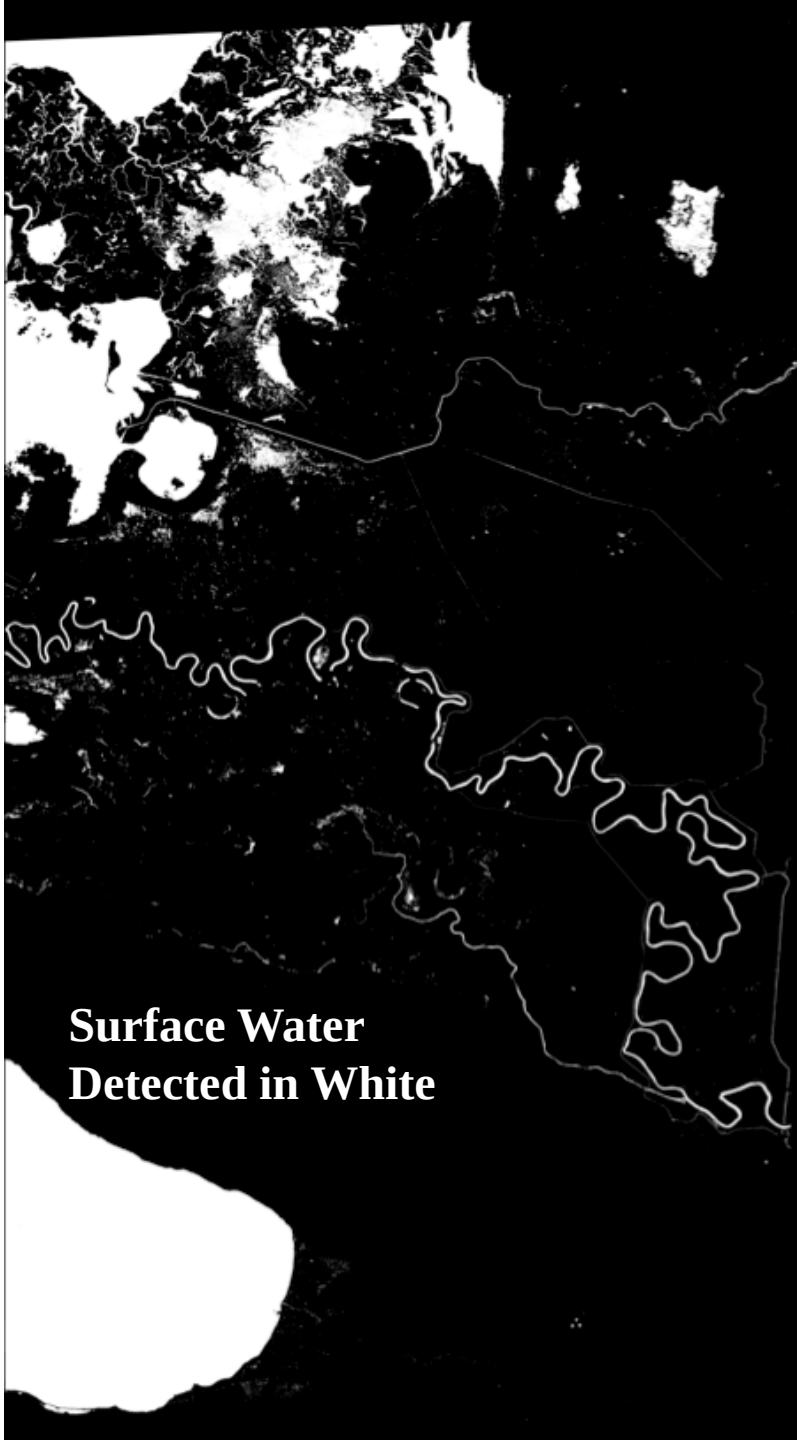
Worldview-2 Processed Data (Binary TIF File)

Surface Water in White

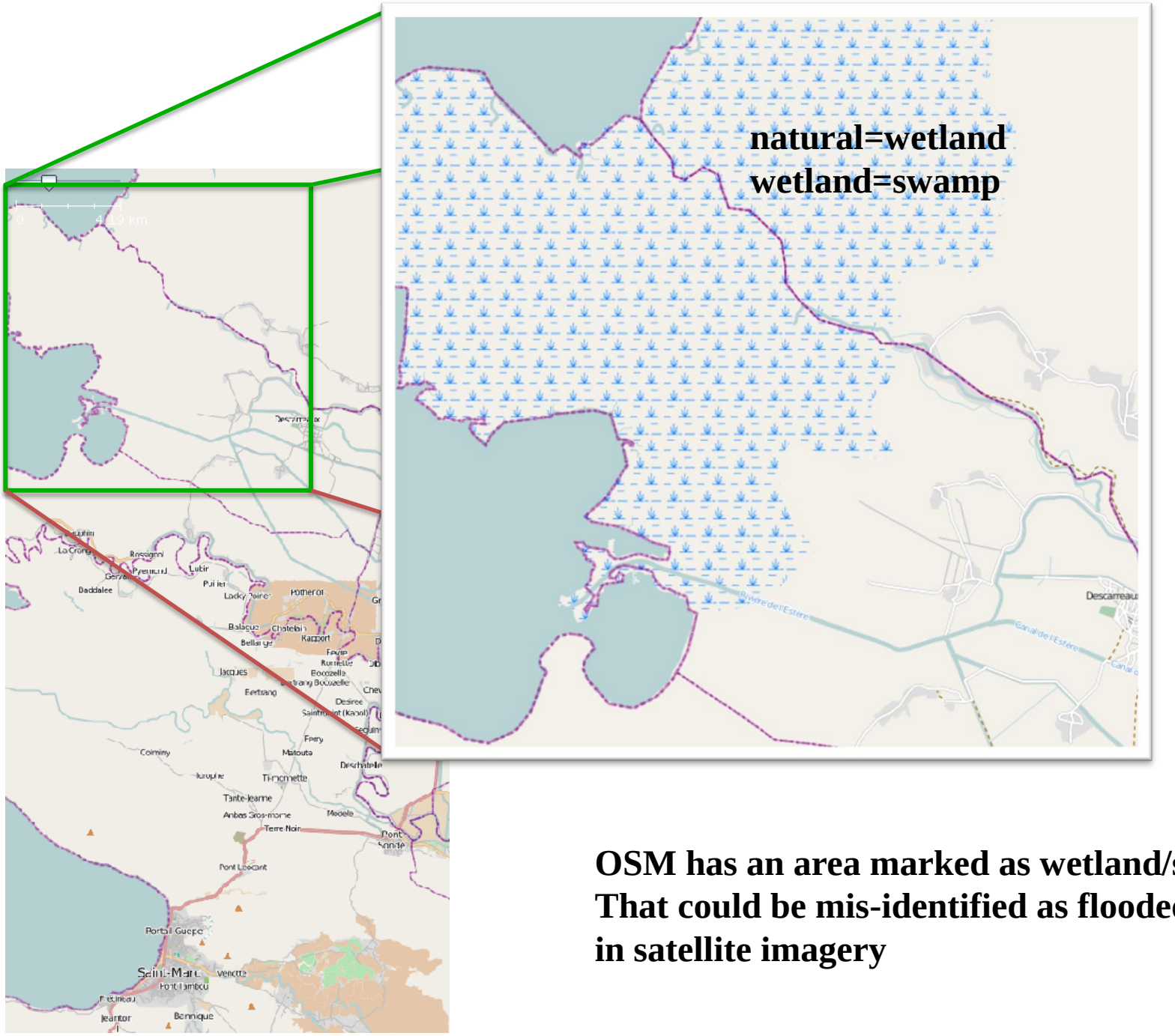
Files: Haiti_RWD_binary_water_0.012.tif
Size is 9419, 17304
Coordinate System is:
GEOGCS["WGS 84",
DATUM["WGS_1984",
SPHEROID["WGS 84",6378137,298.257223563,
AUTHORITY["EPSG","7030"]],
AUTHORITY["EPSG","6326"]],
PRIMEM["Greenwich",0],
UNIT["degree",0.0174532925199433],
AUTHORITY["EPSG","4326"]]
Origin = (-72.761256,19.38983)
Pixel Size = (0.000018,-0.000018)

~2m/pixel resolution

Image Structure Metadata:
INTERLEAVE=BAND
Corner Coordinates:
Upper Left (-72.7612560, 19.3898340)
Lower Left (-72.7612560, 19.0783620)
Upper Right (-72.5917140, 19.3898340)
Lower Right (-72.5917140, 19.0783620)
Center (-72.6764850, 19.2340980)
Band 1 Block=9419x1 Type=Byte, ColorInterp=Gray


Surface Water
Detected in White

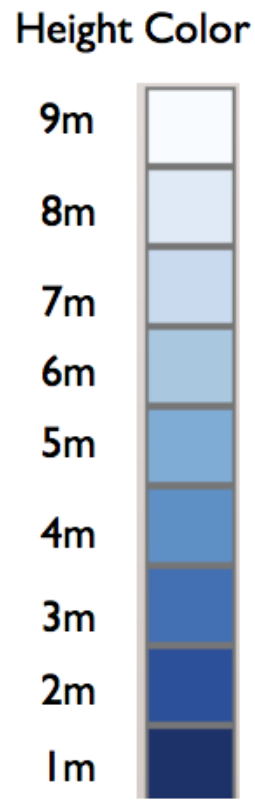

OpenStreetMap
RN 1
RN 1
RN 1
L'Estere
Desormeaux
Daddalee
Gravé
Balaque
Chatelain
Rapport
Jacques
Bertrand Boccazelle
Desiree
Saintmaint (Kapol)
Ducas
Segulin
Ferry
Matouta
Tinomette
Tante-Jeanne
Anbas Gros-morne
Terre Noir
Pont Lescant
Portail Guepe
Saint-Marc
Pont Tambou
Jeanton
Bannique



OSM has an area marked as wetland/swamp
That could be mis-identified as flooded area in satellite imagery

Height Above Nearest Drainage: In Black, Areas to be masked based on Digital Elevation Model

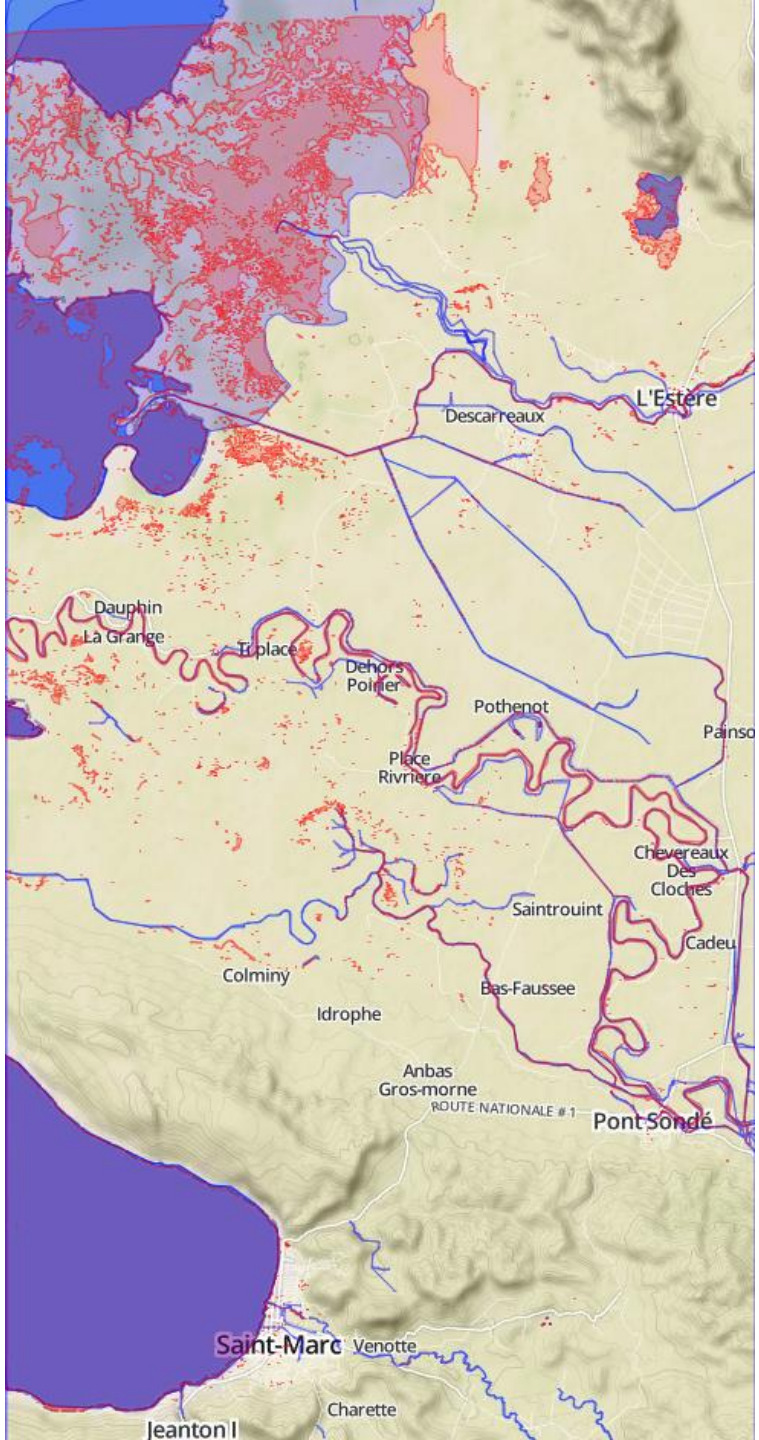
Removed:
46,297 out of 23,659,581

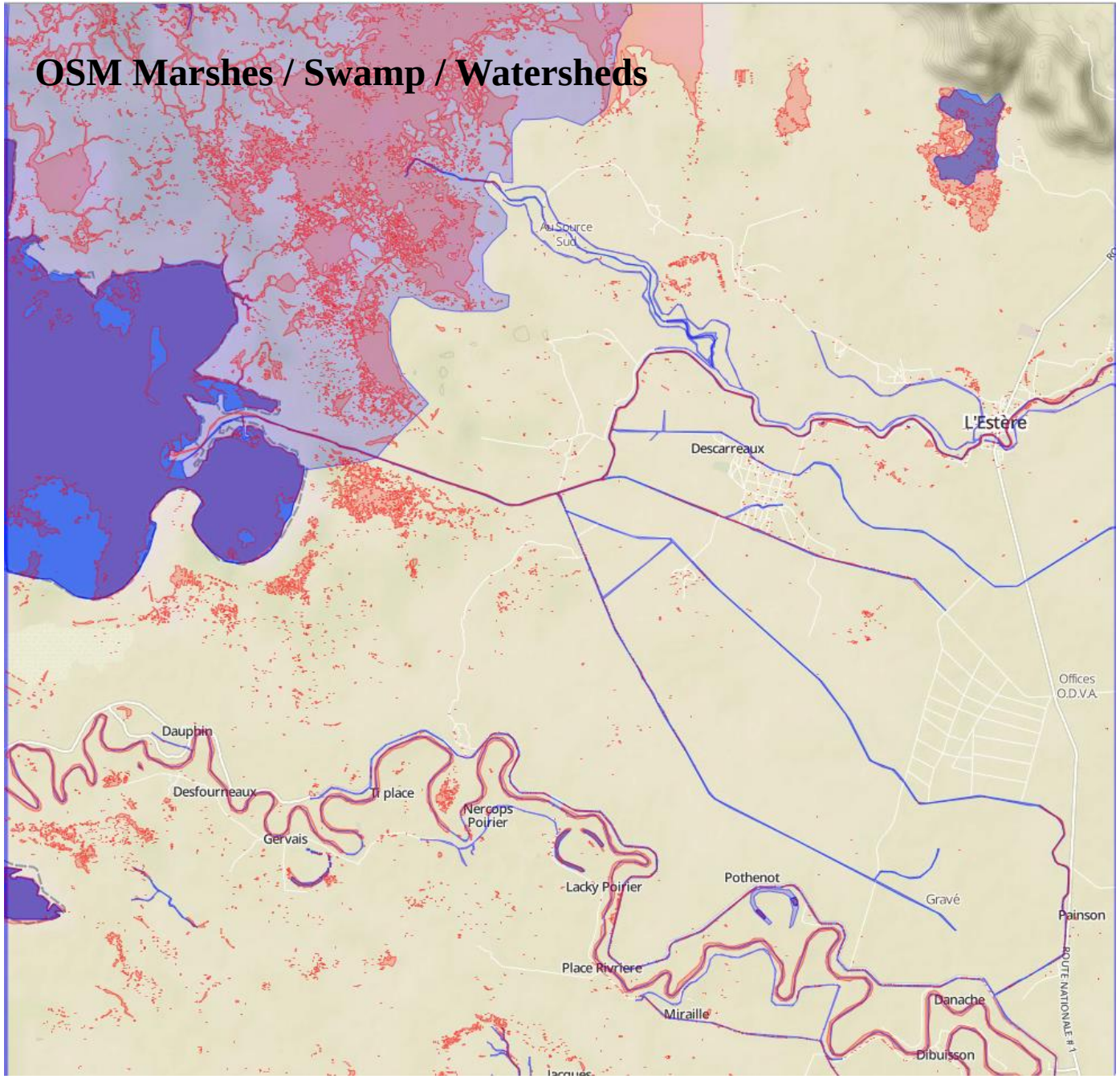


https://maps.google.com
Terrain Map

Resulting Zoomable Flood Map In Browser

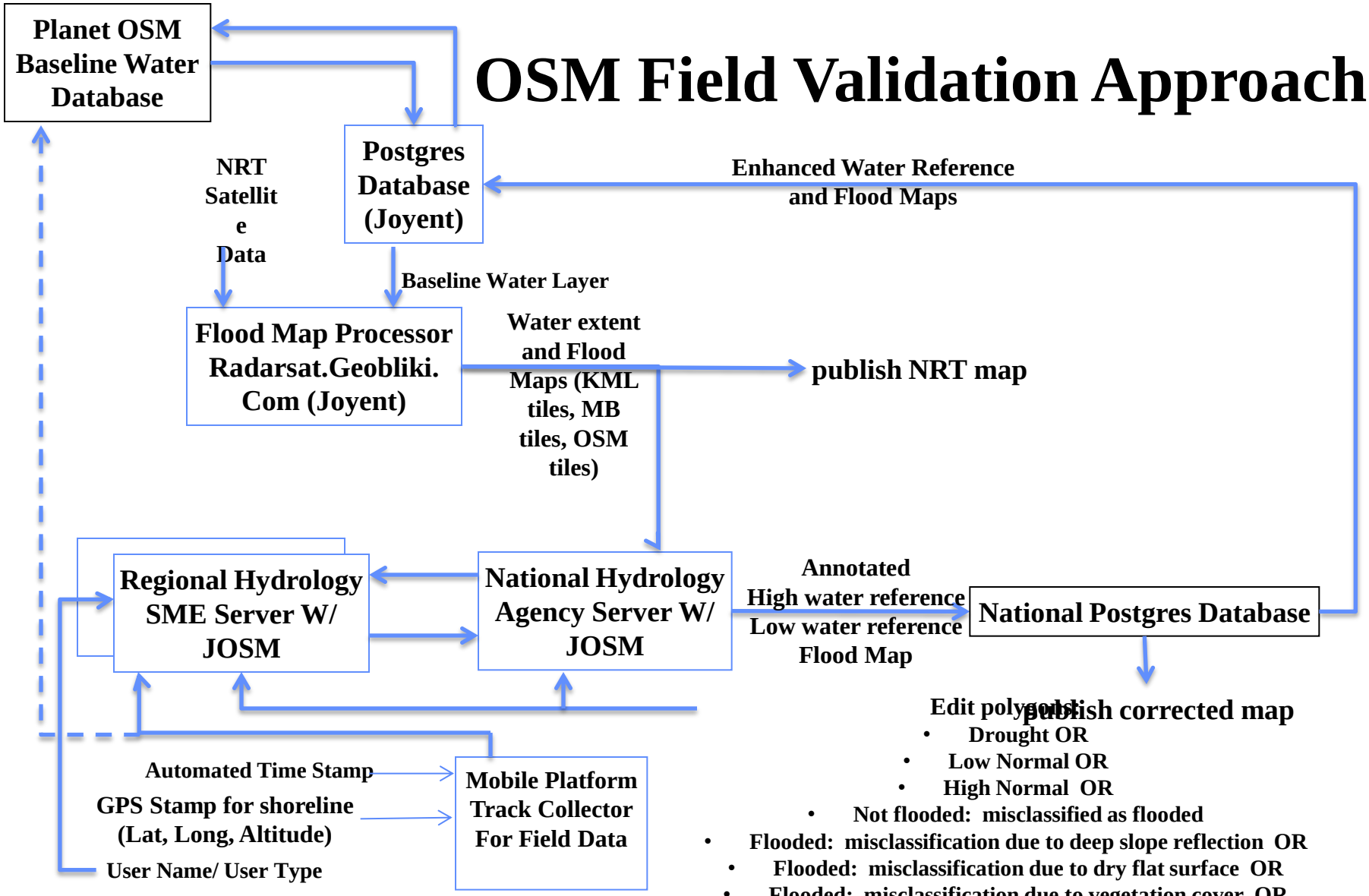
Red: Surface Water (after HAND masking)
Blue: OSM Reference Water
Background: Terrain Map From Mapbox



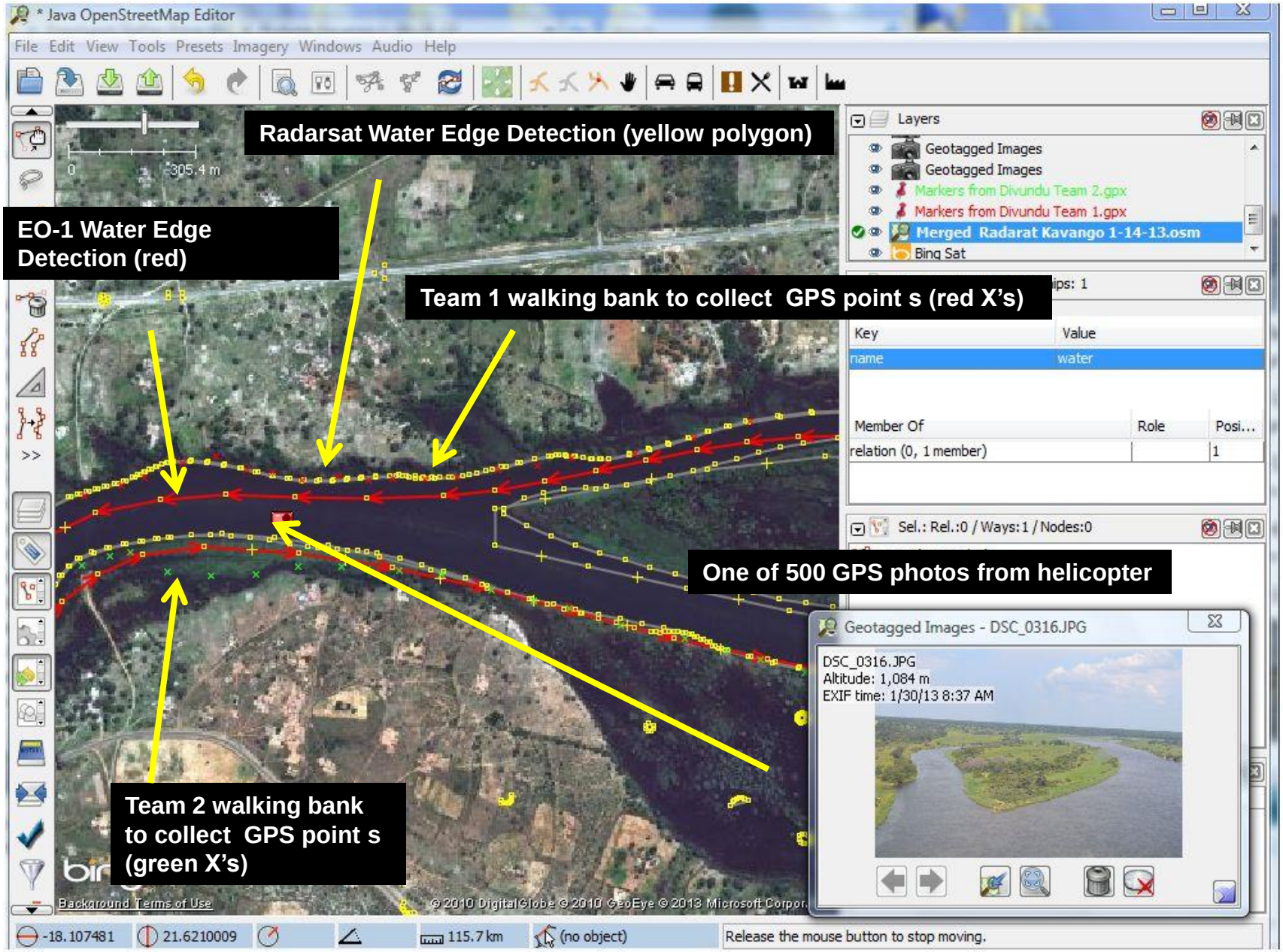


OSM Marshes/Watershed Tags Are Important

OSM Field Validation Approach



Ground Cal/Val Exercise with Radarsat, EO-1, Ground Team, Helicopter team, OpenStreetMap, Crowd Sourcing on Kavango river in Namibia 1-30-13



Integrated Water Edge Detection Display with Boat GPS Measurements, GPS located photos, Radarsat/EO-1 water edge detections